IS 8504-6 (2012): Electrical Insulating Materials - Termal Endurance Properties, Part 6: Determination of Relative Thermal Endurance Index (RTE) of Insulating Material [ETD 2: Solid Electrical Insulating Materials and Insulation Systems]

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भारतीय मानक

विद्युत रोधन सामग्रियाँ — ऊष्मा सहता गुणधर्म

भाग 6 रोधन सामग्री की आपेक्षिक ऊष्मा रोधी सूचकाँक (आर.टी.ई.) ज्ञात करना

Indian Standard

ELECTRICAL INSULATING MATERIALS — THERMAL ENDURANCE PROPERTIES

PART 6 DETERMINATION OF RELATIVE THERMAL ENDURANCE INDEX (RTE) OF AN INSULATING MATERIAL

ICS 19.020; 29.020; 29.035.01

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Solid Electrical Insulating Materials and Insulating Systems Sectional Committee, ETD 02

NATIONAL FOREWORD

This Indian Standard (Part 6) which is identical with IEC 60216-5 : 2008 'Electrical insulating materials — Thermal endurance properties — Part 5: Determination of relative thermal endurance index (RTE) of an insulating material' issued by the International Electrotechnical Commission (IEC) was adopted by the Bureau of Indian Standards on the recommendation of the Solid Electrical Insulating Materials and Insulating Systems Sectional Committee and approval of the Electrotechnical Division Council.

The text of IEC Standard has been approved as suitable for publication as an Indian Standard without deviations. Certain terminology and conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.

b) Comma (,) has been used as a decimal marker, while in Indian Standards the current practice is to use a point (.) as the decimal marker.

In this adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards, which are to be substituted in their respective places are listed below along with their degree of equivalence for the editions indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 60216-1 : 2001 Electrical insulating materials — Properties of thermal endurance — Part 1: Ageing procedures and evaluation of test results	IS 8504 (Part 1) : 2012 Electrical insulating materials — Thermal endurance properties: Part 1 Ageing procedures and evaluation of test results (*second revision*)	Identical
IEC 60216-2 Electrical insulating materials — Thermal endurance properties — Part 2: Determination of thermal endurance properties of electrical insulating materials — Choice of test criteria	IS 8504 (Part 2) : 2012 Electrical insulating materials — Thermal endurance properties: Part 2 Determination of thermal endurance properties of electrical insulating materials — Choice of test criteria (*first revision*)	Identical to IEC 60216-2 : 2005
IEC 60216-3 : 2006 Electrical insulating materials — Thermal endurance properties — Part 3: Instructions for calculating thermal endurance characteristics	IS 8504 (Part 4) : 2012 Electrical insulating materials — Thermal endurance properties: Part 4 Instructions for calculating thermal endurance characteristics (*first revision*)	Identical

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

ELECTRICAL INSULATING MATERIALS — THERMAL ENDURANCE PROPERTIES

PART 6 DETERMINATION OF RELATIVE THERMAL ENDURANCE INDEX (RTE) OF AN INSULATING MATERIAL

1 Scope

This part of IEC 60216 specifies the experimental and calculation procedures to be used for deriving the relative thermal endurance index of a material from experimental data obtained in accordance with the instructions of IEC 60216-1 and IEC 60216-2. The calculation procedures are supplementary to those of IEC 60216-3.

Guidance is also given for assessment of thermal ageing after a single fixed time and temperature, without extrapolation.

The experimental data may in principle be obtained using destructive, non-destructive or proof tests, although destructive tests have been much more extensively employed. Data obtained from non-destructive or proof tests may be “censored”, in that measurement of times taken to reach the endpoint may have been terminated at some point after the median time but before all specimens have reached end-point (see IEC 60216-1).

Guidance is given for preliminary assignment of a thermal class for an insulating material, based upon the thermal ageing performance.

The calculation procedures of this standard also apply to the determination of the thermal class of an electrical insulation system when the thermal stress is the prevailing ageing factor.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60216-1:2001, *Electrical insulating materials – Properties of thermal endurance – Part 1: Ageing procedures and evaluation of test results*

IEC 60216-2, *Electrical insulating materials – Thermal endurance properties – Part 2: Determination of thermal endurance properties of electrical insulating materials – Choice of test criteria*

IEC 60216-3:2006, *Electrical insulating materials – Thermal endurance properties – Part 3: Instructions for calculating thermal endurance characteristics*

3 Terms, definitions, symbols, units and abbreviations

For the purposes of this document, the following terms, definitions, symbols, units and abbreviated terms apply.

3.1 Terms, abbreviations, and definitions

3.1.1
electrical insulating material
EIM
solid or fluid with negligibly low electric conductivity, or a simple combination of such materials, used to separate conducting parts at different electrical potential in electrotechnical devices

3.1.2
assessed thermal endurance index
ATE
numerical value of the temperature in degrees Celsius, up to which the reference EIM possesses known, satisfactory service performance in the specified application

NOTE 1 The value of the ATE may vary between applications for the same material.

NOTE 2 Sometimes referred to as “absolute” thermal endurance index.

3.1.3
candidate EIM
material for which an estimate of the thermal endurance is required to be determined

NOTE The determination is made by simultaneous thermal ageing of the material and a reference EIM.

3.1.4
reference EIM
material with known thermal endurance, preferably derived from service experience, used as a reference for comparative tests with the candidate EIM

3.1.5
central second moment of a data group
sum of the squares of the differences between the data values and the value of the group mean divided by the number of data in the group

3.1.6
correlation time
estimated time to endpoint of the reference EIM at a temperature equal to its assessed thermal endurance (ATE) in degrees Celsius

3.1.7
degrees of freedom
number of data values minus the number of parameter values

3.1.8
standard error
standard error of an estimate of the true value of a data group property is the value of the standard deviation of the hypothetical sampling population of which the group property may be considered to be a member

NOTE 1 For the group mean it is equal to the group standard deviation divided by the square root of the number of data in the group, and indicates the uncertainty in the true value of the mean.

NOTE 2 This standard is concerned only with means and the difference between two means (see Clause A.2).

3.1.9
standard deviation
square root of the variance of a data group or sub-group

3.1.10
relative thermal endurance index
RTE
numerical value of the temperature in degrees Celsius at which the estimated time to endpoint of the candidate EIM is the same as the estimated time to endpoint of the reference EIM at a temperature equal to its assessed thermal endurance (ATE)

3.1.11
variance of a data group
sum of the squares of the deviations of the data from a reference level defined by one or more parameters, divided by the number of degrees of freedom

NOTE The reference level may, for example, be a mean value (1 parameter) or a line (2 parameters, in this standard, the slope and the intercept with the y axis).

3.2 Symbols and units

a_A	Regression coefficient (y-intercept) of thermal endurance equation for reference EIM
a_B	Regression coefficient (y-intercept) of thermal endurance equation for candidate EIM
b_A	Regression coefficient (slope) of thermal endurance equation for reference EIM
b_B	Regression coefficient (slope) of thermal endurance equation for candidate EIM
X	Variable for statistical analysis equal to $1/(\vartheta + \Theta_0)$
Y	Variable for statistical analysis equal to $\ln(\tau)$
ϑ	Ageing temperature in determination of RTE
Θ_0	Temperature on Kelvin scale equal to 0 °C
τ	Time to endpoint
τ_c	Estimated time to endpoint of reference EIM at a temperature equal to ATE (“correlation time”)
$\mu_{2(A)}$	Central second moment of x values for reference EIM
$\mu_{2(B)}$	Central second moment of x values for candidate EIM
n_A	Number of y values for reference EIM data
n_B	Number of y values for candidate EIM data
T	Student’s t distributed stochastic variable
s	Standard error of the difference of two means
s_A^2	Variance of y values for reference EIM data
s_B^2	Variance of y values for candidate EIM data
$\bar{x}_A$	General mean of x-values for reference EIM data
$\bar{x}_B$	General mean of x-values for candidate EIM data
$\bar{y}_A$	General mean of y-values for reference EIM data
$\bar{y}_B$	General mean of y-values for candidate EIM data
θ_A	Temperature in degrees Celsius equal to ATE
θ_B	Temperature in degrees Celsius equal to RTE

$\hat{X}_B$	x value corresponding to θ_B
$\hat{X}_A$	x value corresponding to θ_A
$\theta_{c(B)}$	Lower confidence limit of θ_B
$\theta_{c(A)}$	Lower confidence limit of θ_A
$X_{L(B)}$	x value corresponding to lower confidence limit of θ_B
$X_{L(A)}$	x value corresponding to lower confidence limit of θ_A
Δ_B	Lower confidence interval of θ_B
Δ_A	Lower confidence interval of θ_A
$HIC_{B(c)}$	Halving interval of candidate EIM at a time equal to τ_c
s_D^2	Variance associated with the difference between the mean y-values for the two materials
n_D	Degrees of freedom of s_D^2
υ_A, υ_B	Logarithms of the longest mean times to endpoint for materials A and B
b_r	Intermediate variable: adjusted value of b for calculation of temperature confidence interval
s_r	Intermediate variable: adjusted value of s for calculation of temperature confidence interval

3.3 Objectives of RTE determination

The objectives of the determination are as follows.

a) To exploit an assumed relationship between thermal endurance (with an appropriate test criterion for ageing) and service performance, and to use this to predict a value for a preliminary assessment of service temperature of a material for which there is relatively little service experience (by comparison with a known reference EIM, see Clauses 4 and 5).

NOTE In the majority of cases, this will involve extrapolation to a longer time and/or lower temperature than in the experimental data. This extrapolation should be kept to a minimum by appropriate choice of ageing temperatures and times, since the uncertainty in the result increases rapidly as the extrapolation is increased. However, even when there is no extrapolation, the uncertainty is still finite, on account of the variances of the experimental data and experimental errors.

b) To improve the precision of a thermal endurance determination by reduction of systematic errors in the ageing process. If, after ageing, the results for the reference EIM are found to be significantly different from earlier experience, this may indicate changes in material or equipment. This may be investigated and possibly corrected. In any case, the simultaneous ageing of reference and candidate will at least partially compensate for systematic changes. Statistical procedures for use in assessing the significance of changes are given in Annex A.

c) To provide instructions for assigning a thermal class to an EIM.

4 Experimental procedures

4.1 Selection of reference EIM

The primary requirement for the reference EIM is that it has a known thermal endurance index (ATE) for the application under consideration. The thermal endurance index, if determined by an RTE procedure, is preferably supported by actual service experience (see Annex D).

The expected ageing mechanisms and rates of both materials shall be similar, and relevant to the application.

4.2 Selection of diagnostic test for extent of ageing

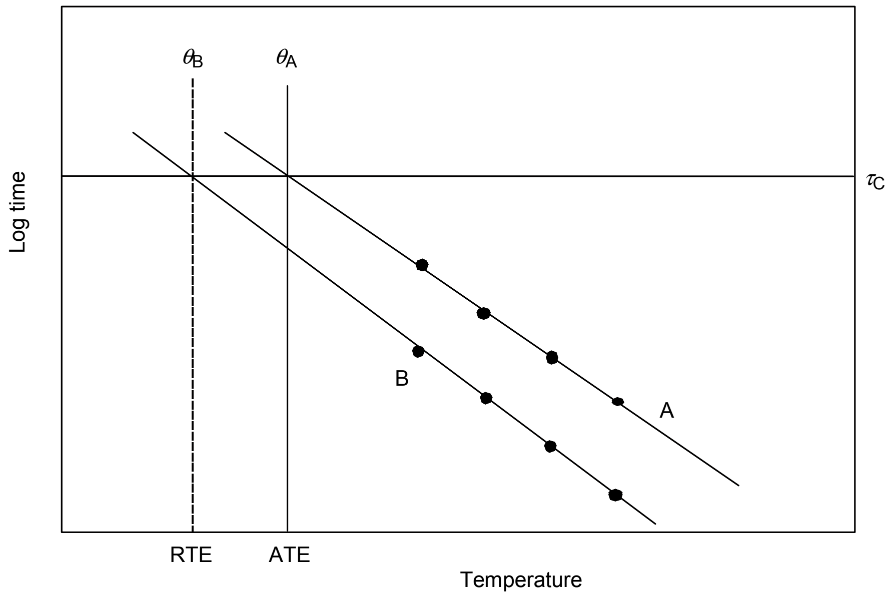
The diagnostic test shall be one considered relevant to the application for which the RTE is required. The same test shall be applied to both reference and candidate EIM.

4.3 Ageing procedures

The number and type of test specimens of each material and the ageing temperatures and times shall be in accordance with the requirements of IEC 60216-1 (5.3.2, 5.4 and the first paragraph of 5.5). At each ageing temperature, the oven load shall comprise appropriate numbers of test specimens of both materials in the same oven. The specimens shall be evenly distributed in the oven so that there is likely to be no systematic difference between the ageing conditions applied to the specimens of the two materials. It is important that test specimens of both materials are aged simultaneously at a minimum of three temperatures to be included in the calculations.

NOTE As an example, while the data represented in Figure 1 would be acceptable for analysis, of the data represented by Figure 2, the lowest temperature group of the candidate EIM and the highest temperature group of the reference cannot be included, since in each case, the specimen group is made up of only one material or one of the two materials did not reach the chosen end point within the test time.

If, when ageing at the selected temperatures is completed, the results from either material do not satisfy the requirements of 6.1 b) of this standard, a further specimen group shall be aged, within the same oven, at an appropriate temperature. This group shall again be composed of the required number and type of specimens of each material.

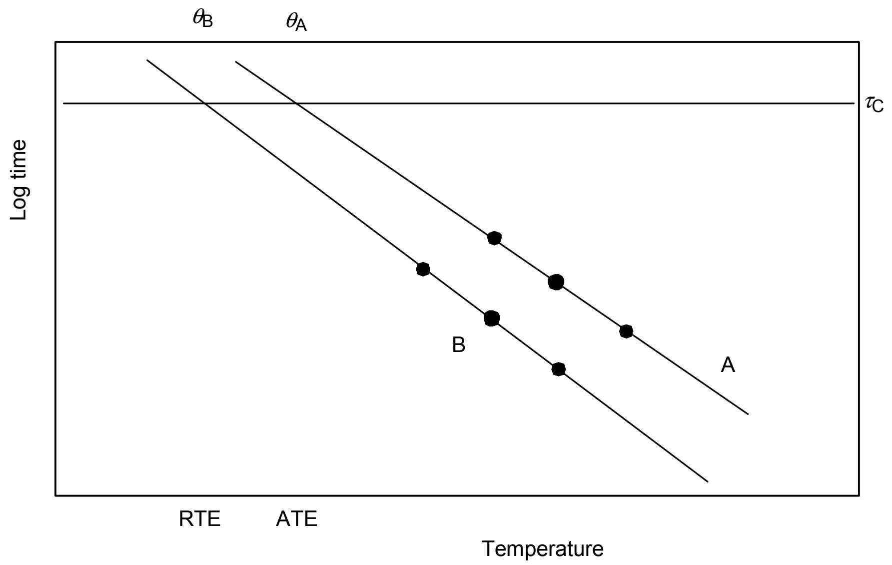


Key

A = reference EIM

B = candidate EIM

Figure 1 – Thermal endurance graphs



Key

A = reference EIM

B = candidate EIM

NOTE The test specimens of both materials are not aged simultaneously at a minimum of three temperatures.

Figure 2 – Unacceptable thermal endurance graphs

5 Calculation procedures

5.1 Thermal endurance data – Calculation of intermediate parameters

Calculation of the thermal endurance equations shall be made in accordance with the instructions of IEC 60216-3.

The following input parameters as set out in Table 1 are needed for the calculations relevant to RTE, and should be recorded (each of the symbols may have either subscript A for reference EIM or B for candidate EIM).

Table 1 – Input parameters for the calculations concerning RTE

Parameter	Symbol in IEC 60216-3	Equation in IEC 60216-3	Symbol in IEC 60216-5	
Slope of regression line	b	(33)	b_A	b_B
Intercept of regression line	a	(34)	a_A	a_B
Weighted mean of x values	$\bar{x}$	(26)	$\bar{x}_A$	$\bar{x}_B$
Central 2nd moment of x values	$\mu_2(x)$	(31)	$\mu_{2(A)}$	$\mu_{2(B)}$
Weighted mean of y values	$\bar{y}$	(27)	$\bar{y}_A$	$\bar{y}_B$
Variance of y values	s^2	(41)	s_A^2	s_B^2
Number of y values	N	(25)	n_A	n_B
Halving interval	HIC	(53)	–	$HIC_{B(c)}$
Largest mean log time to endpoint	$\bar{y}_k$	–	υ_A	υ_B
Lower confidence limit of θ	$\hat{\vartheta}_c$	(50)	$\theta_{c(A)}$	$\theta_{c(B)}$

NOTE If the calculations of IEC 60216-3 are performed by the recommended computer programme, subroutines should be included to record the parameters in a data file which can be recalled for the purposes of the present calculations. Alternatively, the values of $\theta_{c(A)}$ and $\theta_{c(B)}$ may be calculated directly in that program.

The result of the linearity test (IEC 60216-3, 6.3.2) is also needed.

5.2 Calculation of RTE

Calculation of the coefficients of the thermal endurance equations shall be made for both reference and candidate EIMs in accordance with the instructions of 6.1 and 6.2 of IEC 60216-3 (see 5.1 of this standard). From these coefficients the values of τ_c and θ_B shall be calculated as below (see also Figure 1).

a) From the regression coefficients of the reference EIM, calculate the time τ_c corresponding to its ATE:

$$\ln \tau_c = a_A + \frac{b_A}{(\theta_A + \Theta_0)} \tag{1}$$

b) From the regression coefficients of the candidate EIM, calculate the temperature corresponding to the time τ_c :

$$\theta_B = \frac{b_B}{[\ln(\tau_c) - a_B]} - \Theta_0 \tag{2}$$

The required RTE is equal to the value of θ_B in degrees Celsius.

5.3 Statistical and numerical tests

5.3.1 Tests of IEC 60216-3

The statistical and numerical tests of IEC 60216-3 shall be carried out before the calculations of this standard, and their results employed in compiling the report of Clause 6.

5.3.2 Precision of correlation time

Where a reference EIM has been tested on a previous occasion, with the same diagnostic test and ATE, the values of τ_c should be compared using the Student's t-test for the difference of two means. A significant difference may imply a change in the reference EIM itself, a change in the oven equipment or a change in the test apparatus. The cause should be investigated and reported.

Statistical procedures for assessing the significance of differences between values are given in Annex A.

5.3.3 Lower confidence interval of RTE

The lower confidence limit of RTE is calculated from the lower confidence limits of temperature estimates equal to θ_A and θ_B (IEC 60216-3, 6.3.3 b), Equations (46) to (50)).

The lower confidence limit of θ_B, $\theta_{c(B)}$, is calculated as in IEC 60216-3, 6.3.3 b) for a time equal to τ_c and subtracted from θ_B to give the confidence interval Δ_B.

$$X_{L(B)} = \bar{x}_B + \frac{(Y - \bar{y}_B)}{b_r} + \frac{t\, s_r}{b_r} \tag{3}$$

$$Y = \ln \tau_c \quad ; \quad \hat{X}_B = (Y - a_B)/b_B \tag{4}$$

$$\text{where } b_r = b_B - \frac{t^2 s_B^2}{b_B\, \mu_{2(B)}} \tag{5}$$

$$s_r^2 = s_B^2 \left(\frac{b_r}{b_B} + \frac{(\hat{X} - \bar{x}_B)^2}{\mu_{2(B)}} \right) \tag{6}$$

where t is the value of Student's t for n_B degrees of freedom and a significance level of 0,05 (see Table B.3);

$\mu_{2(B)}$ is the central second moment of the x values:

$$\mu_{2(B)} = \frac{1}{n_B} \sum_{i=1}^{k} n_{i(B)} \left(x_{i(B)} - \bar{x}_{(B)} \right)^2 \tag{7}$$

(see IEC 60216-3, 6.2.2 for details).

The lower confidence limit of θ_A, $\theta_{c(A)}$ is calculated as above for a time equal to τ_c and subtracted from θ_A to give the confidence interval Δ_A.

The lower confidence interval of RTE, Δ_R, is then equal to the "Pythagorean" (orthogonal) vector sum of the above two intervals:

$$\Delta_R = \sqrt{(\Delta_A^2 + \Delta_B^2)} \tag{8}$$

5.3.4 Extrapolation

The extrapolation required to estimate the correlation time is calculated for both reference and candidate EIMs as the difference between the logarithm of the correlation time and the greatest value of the mean of the logarithms of the ageing times to endpoint (υ_A or υ_B). The extrapolation required is the greater of these two values.

6 Report

6.1 Results of statistical and numerical tests

The following criteria apply.

a) Linearity of thermal endurance relationships and confidence intervals of TI results of both reference and candidate EIMs (see IEC 60216-3, 6.3.2 and 6.3.3) which shall satisfy the requirements of IEC 60216-3, 7.3.1 and 7.3.2.

b) Extrapolation to the correlation time (see 5.3.4 above): the extrapolation, expressed as the ratio of correlation time to greatest geometric mean ageing time shall be less than 4.

c) Lower confidence interval of RTE (see 5.3.3 above): The value of Δ_R shall be less than the halving interval ($HIC_{B(c)}$) of the candidate EIM at a time equal to the correlation time (see IEC 60216-3, 7.1).

$$HIC_{B(c)} = b_B \left[\frac{1}{((\ln \tau_c / 2) - a_B)} - \frac{1}{(\ln \tau_c - a_B)} \right] \tag{9}$$

6.2 Results

The results shall be determined from the calculations of 5.2 and 5.3.3 as follows.

a) If all three test criteria (see 6.1) are satisfied, the result shall be the value of RTE. The result shall be reported in the format: "RTE according to IEC 60216-5 = xxx".

b) If one of the test criteria is not satisfied, the result shall be the lower 95 % confidence limit of RTE. The result shall be reported in the format: "RTE lower 95 % confidence limit = xxx"

c) If two or more of the criteria are not satisfied, a result in accordance with the requirements of IEC 60216-5 cannot be reported. The result may be reported in the format: "RTE = xxx. (Result not validated by the statistical analysis)".

6.3 Report

The report shall comprise the following:

a) the result;

b) the identification of the reference EIM and its ATE (see Annex D);

c) the diagnostic test employed and the endpoint;

d) the thermal endurance reports according to IEC 60216-1 for the reference and candidate EIMs;

e) the details of the failure of statistical validation for a result in category 6.2 c).

7 Material testing by short-term thermal ageing

There is often a need for short-term thermal ageing tests on materials, e.g. to compare thermal performances of materials having slight chemical modifications with respect to a known reference EIM, or in quality reference testing of insulation containing anti-oxidant

constituents, where ageing at the rated temperature of the material for a period of a few thousand hours could be employed.

The interpretation of such tests can be quite difficult, particularly if the ageing is at a single temperature, with property measurement after a single fixed time. The absence of testing for compliance with a chemical kinetic model leads to a liability to systematic errors caused by equipment or material changes.

It is recommended that in such cases, a reference EIM of similar type and rating as the test material should be aged simultaneously and tested after the same time. A similar analysis to that of Annex A can then be applied to the two sets of property values to establish whether there are significant differences between

a) the candidate EIM and the reference EIM, or

b) the current test values of the reference EIM and the historical values obtained on the same material.

In this analysis, s_1^2 and s_2^2 are the variances of the groups of property values after ageing at the test temperature; $\bar{y}_1$ and $\bar{y}_2$ are the means of these groups (see Equations (A.1) to (A.4)).

Unless otherwise specified, the test for significant difference shall be made at a level of 0,05 (see Table B.1).

If significant differences are not found, it may be assumed that the thermal endurance performances of the two materials being compared are the same. If significant differences are found in case a) above, it is likely that the performance of the candidate EIM will not be the same as that of the reference. If significant differences are found in case b) above, then it is likely that the ageing conditions differ in some way from those originally employed: they should be investigated and the cause established.

8 Insulation classification

When required, the candidate EIM may be assigned to an insulation thermal class in accordance with Table B.1.

Annex A
(informative)

Repeatability of correlation time

A.0 Overview

Where a reference EIM has been tested on a previous occasion, the values of τ_c should be compared. A significant difference may imply a change in the reference EIM itself, or possibly a change in the oven equipment or a change in the test apparatus. The cause should be investigated and reported.

The comparison is made using the Student's t-test for the difference of two means, by the procedures below. The suffices 1 and 2 refer to the two sets of data. In the equations, the values $\bar{y}_1$ and $\bar{y}_2$ are the logarithms of the two values of correlation time.

A.1 F-test for equality of variances

The variances of the y-values for the reference EIMs in the present and previous determinations (s_1^2 and s_2^2) shall be calculated in accordance with the instructions of IEC 60216-3 (6.3.2, Equation (41) or (42)). Their ratio is then tested for equality of the variances by the F-test on a significance level of 0,05 with degrees of freedom n_1-2 and n_2-2 (see Table B.1).

NOTE The symbols s_1^2 and s_2^2 here refer to the estimates of variance for the material on occasions 1 and 2, and not to the within and between classes as given in IEC 60216-3, Equations (41) and (42).

A.2 Standard error of the difference of two means

The values of variance are combined using Equations (A.1) and (A.2) if the values are not significantly different:

$$s_D^2 = \frac{s_1^2\,(n_1-1)+s_2^2\,(n_2-1)}{(n_1+n_2-2)}\left(\frac{1}{n_1}+\frac{1}{n_2}\right) \qquad \text{(A.1)}$$

$$n_D = (n_1+n_2-2) \qquad \text{(A.2)}$$

If the values of variance are significantly different, then Equations (A.3) and (A.4) shall be used. In this case the value n_D may not be an integer. The nearest integer (rounded up or down as appropriate) shall then be employed in subsequent calculations.

$$s_D^2 = \frac{s_1^2}{n_1}+\frac{s_2^2}{n_2} \qquad \text{(A.3)}$$

$$n_D = \frac{\left(s_D^2\right)^2}{\frac{\left(\frac{s_1^2}{n_1}\right)^2}{n_1 - 1} + \frac{\left(\frac{s_2^2}{n_2}\right)^2}{n_2 - 1}} \qquad \text{(A.4)}$$

The square root of the value of s_D^2 is the standard error, s, of the difference of the general means of the y-values.

NOTE When the values of n_1 and n_2 are equal, Equations (A.1) and (A.3) become identical.

A.3 Student's *t*-test for difference of two means

When two estimates of a mean value (which in this case includes estimates by linear regression) are obtained from separate sets of data and the true values are expected to be the same, their equality may be tested by the Student's t-test. The principle of this test is to calculate the ratio of the difference of the mean estimates to the standard error of this difference. The variances of the two data sets are combined in the same way as the variances in Clause A.2 and the standard error calculated.

The value of t is the ratio of the difference of the means to the standard error:

$$t = \frac{\left(\bar{y}_1 - \bar{y}_2\right)}{\sqrt{s_D^2}} \qquad \text{(A.5)}$$

The associated number of degrees of freedom is n_D or the nearest integer. If the value of t is greater than the value for a significance level of 0,05 given in Table B.2, the difference is considered to be significant and its cause should be investigated.

For the purposes of 5.3.2, in the calculations of Equations (A.1) to (A.5), the values of s_1^2 and s_2^2 are obtained using Equation (45) of IEC 60216-3 (6.3.3), viz:

$$s_Y^2 = \frac{s^2}{N}\left[1 + \frac{\left(X - \bar{x}\right)^2}{\mu_2(x)}\right]$$

$$s_1^2 = \left|N\, s_Y^2\right|_1 \qquad \text{and} \qquad s_2^2 = \left|N\, s_Y^2\right|_2 \qquad \text{(A.6)}$$

The values of $\bar{y}_1$ and $\bar{y}_2$ are the logarithms of the two values of τ_c .

A.4 Combination of data

If the two results for correlation time and the two values of variance are not significantly different, a more precise estimate of the logarithm of correlation time may be obtained by merging the two sets of data:

$$\bar{y} = \frac{\left(n_1\bar{y}_1 + n_2\bar{y}_2\right)}{\left(n_1 + n_2\right)} \qquad \text{(A.7)}$$

$$s^2 = \frac{s_1^2(n_1 - 1) + s_2^2(n_2 - 1)}{(n_1 + n_2 - 2)} \qquad \text{(A.8)}$$

Annex B
(informative)

Thermal class assignment

Table B.1 relates the thermal class assignment, when required, to the value of ATE/RTE, in accordance with IEC 60085.

Table B.1 – Thermal class equivalents for insulating material

	ATE/RTE			Thermal class		Letter designation
	°C			°C		
	≥90	<105		90		Y
	≥105	<120		105		A
	≥120	<130		120		E
	≥130	<155		130		B
	≥155	<180		155		F
	≥180	<200		180		H
	≥200	<220		200		N
	≥220	<250		220		R
	≥250	<275		250		

a If desired, the letter designation may be added in parentheses, e.g. Class 180 (H). Where space is a factor, such as on a nameplate, the product TC may elect to use only the letter designation.

b Designations of thermal classes over 250 shall increase by increments of 25 and be designated accordingly.

Tables B.2 and B.3 give the values of F and of Student's t for significance levels of 0,05 and 0,005.

NOTE 1 The significance, p, is equal to 1-P, where P is the probability of the stochastic variable (F or t) being less than the tabulated value.

The columns of the F table (Table B.2) represent the number of degrees of freedom of the numerator and the rows the number of degrees of freedom of the denominator.

The columns of the t table (Table B.3) represent the number of degrees of freedom and the rows the significance level (p).

NOTE 2 The tables include significance levels of 0,05 and 0,005 in case they should at any time be needed. For present purposes, the 0,005 values may be deleted, but they are on record for future use.

Table B.2 – F– function; p = 0,05

	10	11	12	13	14	15	16	17	18	19	20	25	30	40	50	100	500
10	2,978	2,943	2,913	2,887	2,865	2,845	2,828	2,812	2,798	2,785	2,774	2,730	2,700	2,661	2,637	2,588	2,548
11	2,854	2,818	2,788	2,761	2,739	2,719	2,701	2,685	2,671	2,658	2,646	2,601	2,570	2,531	2,507	2,457	2,415
12	2,753	2,717	2,687	2,660	2,637	2,617	2,599	2,583	2,568	2,555	2,544	2,498	2,466	2,426	2,401	2,350	2,307
13	2,671	2,635	2,604	2,577	2,554	2,533	2,515	2,499	2,484	2,471	2,459	2,412	2,380	2,339	2,314	2,261	2,218
14	2,602	2,565	2,534	2,507	2,484	2,463	2,445	2,428	2,413	2,400	2,388	2,341	2,308	2,266	2,241	2,187	2,142
15	2,544	2,507	2,475	2,448	2,424	2,403	2,385	2,368	2,353	2,340	2,328	2,280	2,247	2,204	2,178	2,123	2,078
16	2,494	2,456	2,425	2,397	2,373	2,352	2,333	2,317	2,302	2,288	2,276	2,227	2,194	2,151	2,124	2,068	2,022
17	2,450	2,413	2,381	2,353	2,329	2,308	2,289	2,272	2,257	2,243	2,230	2,181	2,148	2,104	2,077	2,020	1,973
18	2,412	2,374	2,342	2,314	2,290	2,269	2,250	2,233	2,217	2,203	2,191	2,141	2,107	2,063	2,035	1,978	1,929
19	2,378	2,340	2,308	2,280	2,256	2,234	2,215	2,198	2,182	2,168	2,155	2,106	2,071	2,026	1,999	1,940	1,891
20	2,348	2,310	2,278	2,250	2,225	2,203	2,184	2,167	2,151	2,137	2,124	2,074	2,039	1,994	1,966	1,907	1,856
25	2,236	2,198	2,165	2,136	2,111	2,089	2,069	2,051	2,035	2,021	2,007	1,955	1,919	1,872	1,842	1,779	1,725
30	2,165	2,126	2,092	2,063	2,037	2,015	1,995	1,976	1,960	1,945	1,932	1,878	1,841	1,792	1,761	1,695	1,637
40	2,077	2,038	2,003	1,974	1,948	1,924	1,904	1,885	1,868	1,853	1,839	1,783	1,744	1,693	1,660	1,589	1,526
50	2,026	1,986	1,952	1,921	1,895	1,871	1,850	1,831	1,814	1,798	1,784	1,727	1,687	1,634	1,599	1,525	1,457
100	1,927	1,886	1,850	1,819	1,792	1,768	1,746	1,726	1,708	1,691	1,676	1,616	1,573	1,515	1,477	1,392	1,308
500	1,850	1,808	1,772	1,740	1,712	1,686	1,664	1,643	1,625	1,607	1,592	1,528	1,482	1,419	1,376	1,275	1,159

F– function; p = 0,005

	10	11	12	13	14	15	16	17	18	19	20	25	30	40	50	100	500
10	5,847	5,746	5,661	5,589	5,526	5,471	5,422	5,379	5,340	5,305	5,274	5,153	5,071	4,966	4,902	4,772	4,666
11	5,418	5,320	5,236	5,165	5,103	5,049	5,001	4,959	4,921	4,886	4,855	4,736	4,654	4,551	4,488	4,359	4,252
12	5,085	4,988	4,906	4,836	4,775	4,721	4,674	4,632	4,595	4,561	4,530	4,412	4,331	4,228	4,165	4,037	3,931
13	4,820	4,724	4,643	4,573	4,513	4,460	4,413	4,372	4,334	4,301	4,270	4,153	4,073	3,970	3,908	3,780	3,674
14	4,603	4,508	4,428	4,359	4,299	4,247	4,200	4,159	4,122	4,089	4,059	3,942	3,862	3,760	3,698	3,569	3,463
15	4,424	4,329	4,250	4,181	4,122	4,070	4,024	3,983	3,946	3,913	3,883	3,766	3,687	3,585	3,523	3,394	3,287
16	4,272	4,179	4,099	4,031	3,972	3,920	3,875	3,834	3,797	3,764	3,734	3,618	3,539	3,437	3,375	3,246	3,139
17	4,142	4,050	3,971	3,903	3,844	3,793	3,747	3,707	3,670	3,637	3,607	3,492	3,412	3,311	3,248	3,119	3,012
18	4,030	3,938	3,860	3,793	3,734	3,683	3,637	3,597	3,560	3,527	3,498	3,382	3,303	3,201	3,139	3,009	2,901
19	3,933	3,841	3,763	3,696	3,638	3,587	3,541	3,501	3,465	3,432	3,402	3,287	3,208	3,106	3,043	2,913	2,804
20	3,847	3,756	3,678	3,611	3,553	3,502	3,457	3,416	3,380	3,347	3,318	3,203	3,123	3,022	2,959	2,828	2,719
25	3,537	3,447	3,370	3,304	3,247	3,196	3,151	3,111	3,075	3,043	3,013	2,898	2,819	2,716	2,652	2,519	2,406
30	3,344	3,255	3,179	3,113	3,056	3,006	2,961	2,921	2,885	2,853	2,823	2,708	2,628	2,524	2,459	2,323	2,207
40	3,117	3,028	2,953	2,888	2,831	2,781	2,737	2,697	2,661	2,628	2,598	2,482	2,401	2,296	2,230	2,088	1,965
50	2,988	2,900	2,825	2,760	2,703	2,653	2,609	2,569	2,533	2,500	2,470	2,353	2,272	2,164	2,097	1,951	1,821
100	2,744	2,657	2,583	2,518	2,461	2,411	2,367	2,326	2,290	2,257	2,227	2,108	2,024	1,912	1,840	1,681	1,529
500	2,562	2,476	2,402	2,337	2,281	2,230	2,185	2,145	2,108	2,075	2,044	1,922	1,835	1,717	1,640	1,460	1,260

Table B.3 – t–function

	10	11	12	13	14	15	16	17	18	19	20	25	30	40	50	100	500
p = 0,05	1,812	1,796	1,782	1,771	1,761	1,753	1,746	1,740	1,734	1,729	1,725	1,708	1,697	1,684	1,676	1,660	1,648
p = 0,005	3,169	3,106	3,055	3,012	2,977	2,947	2,921	2,898	2,878	2,861	2,845	2,787	2,750	2,704	2,678	2,626	2,586

Annexe C
(informative)

Programme informatique

C.1 Computer programs for IEC 60216-5:2008 (RTE)

C.1.1 General

The standard is accompanied by a CDROM.

This CDROM contains three programs for calculation of the Relative Thermal Endurance Index of an insulating material, from data in accordance with IEC 60216-1 and 60216-3. It also contains a pair of data files for trial purposes.

All programs are supplied as source code, suitable for Microsoft Quick Basic 4.5 or Professional Basic v.7 (to enable use with Visual Basic, considerable editing will probably be required) and as executable program files to run in a DOS window under any variety of Windows. For optimum performance, the DOS window should be full screen.

C.1.2 Entry.exe and Entry.bas

This is identical to the data entry file supplied in an annex of IEC 60216-3. A separate set of data is required for each material, Control and Candidate.

C.1.3 IEC 216-5.exe and IEC 216-5.bas

This program is an enhanced version of the program supplied in an annex of IEC 60216-3. It has been enhanced by addition of a procedure to record to a data file the intermediate data required for calculation of RTE. When the experimental data are processed, the intermediate data are automatically saved to a file with the same name as the experimental data file and the ending ".int". For example, a data file n3.dst of destructive test data would generate an intermediate file n3.int. The thermal endurance graph is drawn to screen for each material, and the statistical test results are reported.

C.1.4 RTE.exe and RTE.bas

This program requests the intermediate data files for Control and Candidate, and performs the calculations of IEC 60216-5, giving the RTE and its confidence interval, the halving intervals of both materials (HIC), the correlation time and the ratio of the correlation time to the longest time-to-endpoint (extrapolation). These values are required for the purposes of 6.1 and 6.2 of the standard.

C.2 Data file structure

C.2.1 Experimental data

The structure of these files is explained in IEC 60216-3.

C.2.2 Intermediate data

The following values are recorded, one to each line in the file, which is a simple ASCII text file.

General mean of *x*-values (reciprocal Kelvin temperatures): $\bar{x}$

2nd moment (sample variance) of *x*-values: $\mu_2(x)$

General mean of *y*-values (logarithm of time values) : $\bar{y}$

Non-regression variance of *y*-values: *s*

Number of y-values: *n*

Regression slope: *b*

Regression intercept: *a*

Longest ageing time to endpoint: υ

C.3 Data files

There are two data files, Control.dta and Candidate.dta. For simplicity, these are non-destructive test data, although in practice, destructive tests are much more widely used in RTE work. If used as input for iec216-5.exe, they will generate the corresponding intermediate variable files (which are also provided on the diskette for confirmation purposes).

The operation of RTE.exe can be demonstrated using these files Control.int and Candidate.int.

Annex D
(informative)

Selection of the reference EIM

D.0 Overview

The reference EIM should be selected from the materials that have known and stable thermal endurance characteristics, preferably derived from service experience. The expected ageing mechanisms and rates of both materials should be similar, and relevant to the application.

Details of the service experience and the basis for selection of the reference EIM should be presented to concerned parties who accept and utilize the reference EIM to develop the RTE of a candidate EIM.

D.1 Designation of reference EIM

The designation of reference EIM is to be specified according to this document.

The selector for the reference EIM clarifies:

a) application if available;

b) service experience if available;

c) criteria for selecting the property and the end point values;

d) limits of usage for reference EIM if available.

D.2 Reporting items for reference EIM

The following items have to be reported.

a) Identification of the selected material
   1) Name of manufacturer
   2) Product name, brand and symbol
   3) Generic type of material
   4) Composition e.g. additives. reinforcement, filler, impregnant, combined (or laminated) material, etc.
   5) Type of processing (e.g. moulding, extrusion, casting, laminating, coating, etc.)

b) Service experience of the reference EIM in the electric equipment if available
   1) Role of the insulating material (e.g. mainwall insulation, interturn insulation, intercircuit insulation, etc.)
   2) Condition in the electric device (exclusive usage, combination with other materials)
   3) Minimum thickness of the reference EIM where it fulfils its function

c) Running condition and life of the electric equipment if available, where the reference EIM was used
   1) Kind of electric equipment (e.g. cable, generator, motor, transformer, reactor, etc.)
   2) Environmental conditions if any specialities (e.g. gas or liquid, corrosive atmosphere, humidity, chemicals, radiations)
   3) Rated voltage, frequency, power
   4) Operating conditions (e.g. continuous, intermittent, short time, others)
   5) Maximum temperature in the insulation system or thermal class of the electric equipment
   6) Experienced life time or operated time

Bibliography

IEC 60085: *Electrical insulation – Thermal evaluation and designation*

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